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BOMBARDIER'S MASS PRODUCTION OF THE SNOWMOBILE: THE CANADIAN EXCEPTION?

Chris DeBresson* and Joseph Lampel**

> (Although) the Canadian record in innovation is not quite as dismal as popularly supposed ... a high proportion of innovative products are custom made for one or two customers, and fail to grow into mass produced standardized products.[1]

A disjunction seems to have beset Canadian industrial and economic development in the last forty years. On the one hand, Canada has enjoyed a high rate of growth and a considerable measure of prosperity, placing it well within the ranks of advanced industrial nations; on the other hand, this growth has not produced the prerequisite of advanced industrialization: a dynamic, integrated capital-intensive high technology sector. This absence is particularly striking in view of the increasing evidence of an indigenous and energetic Canadian technological capacity.[2] Even a casual survey of Canadian institutions, engineering and scientific bodies as well as a growing list of inventions which may be branded 'made in Canada' attests to the existence of an unfulfilled potential. Recent evidence proves there is also innovation in Canadian industry even if Canada does not seem to reap some or all of its expected benefits.[3]

Various explanations have been advanced to resolve this paradox. The disjunction between economic and technological development has been ascribed, in turn, to the overbearing presence of foreign multinationals, conservative banking policies, shortage of capital, geographic fragmentation and the small size of market. While a combination of these factors undoubtedly must play an important role in explaining the state of Canadian industrialization, this paper will explore another dimension of the problem. Although the process of technological innovation is intimately bound to the economic process, it is not reduceable to the latter. To begin with: technological activity does not immediately or always translate -- in Canada or elsewhere -- into economic benefits, or *vice versa*. This process of translation is complex and may be more profitably analyzed through a historical rather than a purely economic approach.

Most economic historians have tended to concentrate on the distinction between the inventive and the innovative phase of

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technological activity, thus adopting Schumpeter's seminal distinction. J.J. Brown based his *Ideas in Exile* on such a distinction.[4] In Schumpeter's and Kuznets' visions, innovation is the dynamic element which spurs the rapid growth of an industry and the rapidly-growing industries will engender the economic growth of nations. Not all innovations, however, lead to growth. Beyond Schumpeter's powerful but reductionist concept of the innovating entrepreneur, it is necessary to distinguish between the many different types of innovations and enterprises as well as their different economic impacts. Secondly, it may be that the dynamic economic effects are more a result of how different innovations combine and reinforce each other than the indirect effect of any initial innovation. These qualifications lead us to use two concepts.

CONCEPTS AND DEFINITIONS

The first concept comes from economic history and industrial organization[5] and relates to the production mode. It is important to distinguish between customized production processes, batch production and line production. Such a distinction was useful in comparing nineteenth-century British and American technological development. Economically, innovative mass-produced products have a greater impact than innovations developed for specific and isolated uses. The innovative activity of any country always involves a co-existence between custom, batch and assembly line production. The economic and industrial effects of innovations vary considerably depending on the scope of their applications and the scale of their production. But a common feature of advanced economies is their ability to foster the transformation from a customized innovation into full-fledged mass production where the greatest economic benefits may be reaped. It is in this transition, we suggest, that Canada may so often be deficient. Our first hypothesis is that Canadian industrial innovation tends to remain custom and small batch oriented. Consequently, one can expect to find innovative capability without many industrial and economic benefits.

Let us first define distinctly these production modes. Custom, batch and line production may be distinguished from one another by the number of units produced in a given period. As such, they appear to the economist as part of a continuum. Although these different production modes do not differ by fixed quantities, they are nonetheless qualitatively different. This difference is most notable in the relationship between market and production, on one hand, and the organization of production work on the other. In customized production, the English tailor or gun maker would make, on order, a suit or a gun 'made to measure' the client's needs. In batch production, a manufacturer produces on order a set of parts and assembles them; and he may make a few extra in case of 'lemons' or because he anticipates further demand. The cost of a few extra units is not that great in comparison to the cost of having to manufacture a faulty part again. Also, the opportunity for rapid earnings through the sales of additional units is a further incentive. Line production produces for stock and requires an anticipation of future market demand. The mass producer also tries to shape the market by product design and advertizing, attempting to capture market share through his own distribution system. In addition, the mass producer finances an inventory and invests in specialized equipment.

Another concept which will be useful for subsequent analysis is that of technical 'system.' The French historian of technology, Bertrand Gilles, defines a system of interdependent techniques as a combination whose progress is dependent on the simultaneous progress of all components; the stagnation of one component technique can block the advance of the whole system. The technical momentum generated by a systems innovation is much greater than that of a single innovation.[6]

Systems innovations are most often combined with a standardized, iterative, mass production process. Although some large engineering works are custom made to specifications, they then serve as the equipment for standardized processes of production. Canada more often adopts its technical systems from abroad, leaving the dynamic initiative in economic growth to come from outside the country. In the capital goods sector we often witness large, customized projects such as turbines for hydraulic power plants which are part and parcel of the move towards higher economies of scale. These are the *sine qua non* of mass production. Our corollary hypothesis is that innovations in complex manufacturing are marginal because they are borrowed from abroad. We rarely find the transition to mass production accompanied by associated development of indigenous manufacturing know-how. This lacuna leaves Canadian innovative potential vulnerable to quick imitation by low cost producers.

We will approach these hypotheses through a discussion of the Bombardier case, which illustrates both what is typical and what is atypical about Canadian innovation. The Bombardier story has ramifications that go beyond the Canadian context. Elsewhere, we have analyzed it with respect to the theory of technological life cycles.[7] Here, however, we will focus on this case as a testing ground for hypotheses concerning macro-industrial development in Canada.

THE CASE OF BOMBARDIER'S SNOWMOBILE

The history of Bombardier raises interesting questions. The initial development of what was later to become the snowmobile was made as early as 1927, thus Bombardier's snowmobile technology has a long history.[8] The key invention and development on which his technical leadership and reputation is based dates from 1935.

Joseph-Armand Bombardier, the inventor, had both the leisure that is necessary for the process of trial and error which the development of a new technology requires, as well as a clear vision of the problems to be solved in order to satisfy local needs. Bombardier's living and working environment undoubtedly had an important impact on the direction of his inventive activity. During the idle winter months, Valcourt, his home village, was roadless and snowbound. No 'roadmobiles,' as they used to call them, could reach his Imperial Oil Garage. During the winters, Bombardier had considerable time to ponder the shortcomings of the new mode of transport. His inventive activities in the 1920s and 1930s can be seen as an effort to replace the tire automobile with a track-and-ski automobile as the basic transport vehicle of snowbound northern regions. He developed a vision of an automobile more adapted to the road-less and snowy north. The environment to which he had adapted his technology, however, was transformed by outside factors faster than he could diffuse his *autoneige*. Canada's attraction for American tourists and motorists, its rapid adoption of the Model T Ford and the militarization of the economy paved the roads. Ironically, Bombardier's vehicle would be asked to clear the snow from the roads for the ill-adapted automobiles. Later, the inventor's social vision remained important. When he and his son developed a monocycle version of the snow-mobile, the inventor committed himself to the model more than he had to any previous one. He saw it as a means to help the civilizing mission of his Catholic missionary friends in the Arctic and as a family sport which could break the winter iso-lation of households in rural communities.

Between 1927 and 1937, Bombardier transformed, through adapta-tions, the then-dominant Model T Ford design into an original concept which bore little resemblance to the famous original. He started by simply substituting skis and tracks for the tires of Fords and Fergusons. Iron tracks were simply over-laid on four back tires. By 1931, iron tracks were replaced by rubber tracks with iron traverses; in addition, eight 'crazy' wheels, consisting of brake drums, insured more traction con-tact. By 1935, the core technology of Bombardier's future snowmobile system was already present: the double reinforced rubber tracks and the sprocket motive wheels. The sprocket wheels replaced the motive tires and its teeth inserted them-selves between the tracks, producing better traction and pre-venting the accumulation of snow on the track. In 1936, the 'crazy' wheels were made independent of each other. Separate suspension systems were then introduced: the whole vehicle was lowered and a special frame was designed. Inventive efforts were then directed towards reducing the weight, im-proving the speed and traction of his vehicles. By 1940, Bombardier's *autoneiges* (87 and B12CS models) no longer re-sembled automobiles. For the monocycle version of the snow-mobile, Bombardier's son Germain developed, in 1958, a single wide, continuous tread with two sets of sprocket teeth holes, eliminating wheels altogether. In 1962 a pulley transmission and, in 1965, an automatic transmission for variable speeds were patented. Later, Bombardier Ltd asked Lohnerwerke GMBH of Vienna to develop a rotary engine -- the Rotax -- for the snowmobile. The snowmobile had by now evolved into an original system with most of its own components, an impressive case of technical creation through progressive adaptation.

Another aspect of the growth of the Bombardier firm was the role of the extended family. In 1957, Norman Taylor wrote a thesis on the French-Canadian lack of entrepreneurship.[9] Adopting a Weber-Parsons hypothesis of entrepreneurship based upon small families, Protestant values and separation of family and business, he concluded that Catholic ethics and the extended family were a hindrance to entrepreneurship in Québec. Yet, Joseph-Armand Bombardier seems to have exploited the resources of the extended family for investment, control and transmission of tacit know-how. His brother Alphonse was the accountant, his son Germain was in charge of the rubber component manufacture in nearby Roskin Falls and other relatives were put in charge of other subsidiaries; J. Armand Bombardier's successor was his son-in-law Laurent Beaudoin and although he brought in many Harvard Business School graduates as professional managers, the company is still controlled by the Bombardier family foundation. Informal communication of problems, their context and promising avenues for their solution flowed easily between J. Armand and his inventor son Germain.

We can distinguish five basic periods of Bombardier's snowmobile development: from the 1920s to 1935, when the core technology emerged out of the adaptation of automobiles; from 1935 to the late 1940s, during which Bombardier produced his snowmobiles in batches with few variations; the third period after the Second World War until 1958, during which he extended the applications of sprocket-and-track technology to the use of various industries; the fourth period after 1959 until 1972-5, when mass production of the Ski-Doo became the dominant operation; and, lastly, after the saturation of the North American snowmobile market (1972), when Bombardier Ltd diversified into a multi-product, multi-plant transport equipment manufacturer.

CONTRASTS BETWEEN CUSTOM, BATCH AND LINE PRODUCTION

The contrast between the production operations of these different periods is marked. From 1926 to 1936, Bombardier produced almost one-of-a-kind units to specific orders of individual customers. As a secondary activity of his Imperial Oil gasoline concession, he used his skills as a general mechanic. In the summer of 1936 he produced batches of parts, stocked them in empty neighbourhood barns and, in the fall, moved them into a new manufacturing plant where he hand assembled the models with farm labour, seasonally available in the winter. From that point on, the manufacturing of *auto-neiges* became his major source of income. He employed a pool of skilled mechanics and semi-skilled seasonal labour, producing various models in batches of different sizes. In 1959, with the design of the Ski-Doo, large batch and then line production started a transition that would only be completed after the inventor's death. After 1965, Bombardier Ltd's manufacturing operations were transformed into a Detroit-style assembly line with an overhead, serpentine line, routinized operations, a hierarchical and functional organization, semi-skilled labour and specialized machinery.

The decline of the snowmobile market, however, forced this company to diversity and produce a variety of small vehicles such as monocycles and SeaDoos on its assembly line. In 1975, Bombardier Ltd. acquired M.L. Worthington, a large railway rolling-stock manufacturer and thus embarked on broader diversification into various transport equipment; by then, it became a multi-product, multi-plant transnational operation combining line production of standard designs with batch production of special equipment.

The contrast between the sales and marketing of the different operations is also marked. For half a century, Bombardier's innovations were directed to special applications and therefore were less known. In spite of sustained demand for two of his models -- the B12 Military transporter and the MUSKEG, all-terrain industrial vehicle -- J. Armand Bombardier did not standardize or mass produce any of his models before the Ski-Doo. Integrated line production was only achieved after his death. Just before his death, Bombardier was still concentrating his efforts and financial resources on industrial applications, in particular, the material handling problems of forestry. Given the inventive proclivity of the founder, product designs were almost as numerous as the applications of the technology.

The contrast between periods is also reflected in the length of runs. In 1927, Bombardier sold his first *auto-neige* to a Valcourt Hotel owner who wanted to be able to get his customers in and out of the snowbound village. This model was a success; he ultimately sold about ten of these. Veterinarians and doctors who needed to get to the sick quickly in winter required this adapted automobile. In the 1920s Bombardier came out with a new model every year. Each new model would incorporate a significant new technical component of the eventual technical system. The sales, however, were by unit or in small batches (Table 1). As a batch producer after 1937, Bombardier produced not only for individual customers but also for categories of customers. Such market segments included physicians, veterinarians, ambulance operators, mail services and governments for defence in the arctic, petroleum exploration, forest management and road and sidewalk clearing. This involved anticipating demand and the clientele's buying capacity. But the market niches remained segmented. As a line producer in the 1960s, Bombardier Ltd. sold to the consumer and the mass market. A distribution network was established. Although J. Armand Bombardier did not believe in advertising, the professional, Harvard-trained managers who came into the firm after his death relied heavily on more conventional marketing approaches.

From custom-designed specialty products to product variations for market segments and then finally to a standardized, simple product for the mass consumer market, Bombardier had an increasing economic impact. At first, his adaptations of the automobile only allowed an increase of its use to a few wealthy professionals during the winter months. Later, as Bombardier developed varied industrial applications, the automotive technology was made available to numerous industries which benefitted from increased performance and reduced operating costs. But wide economic impact only occurred when a product for the consumer enabled the workers of the Bombardier factories themselves to acquire, from their salaries, the simple, reliable Ski-Doo which sold at one point for as low as $600. This 'final demand linkage' with the income generation of the production activities resulted in economic growth for the region.

TABLE 1

Total Numbers Sold of Models or Series, 1927-69

YEAR	INTRODUCED INNOVATION	TOTAL SALES
1927	Steel Track over Tires with Front Skis	12
1936	Independent Crazy Wheels; Spring Rear Axle	12
1938	Improved Station Wagon	400
WAR	PRODUCTION	CONTROLS
1940	12-Passenger Troop Carrier (Toboggan-shaped, independent Back Wheel Suspension, on Skis)	4,000
1949	Tractor Tracks T.T.A.	4,000
1950	Tracked Truck	50
1951	MUSKEG	10,000
1959	Skidoo	1,000,000

Table 1 provides an idea of the magnitude of the production runs. The yearly production runs of successful models increase relentlessly, but not smoothly; the scale of production increased by jerks. Little by little, as the market broadened for his product, Bombardier started to exploit economies of scale. The apparent continuum in increase in scale of production, however, obscures two other phenomena: first, the importance of economies of product variation in the custom and batch mode of production and second the strategic decisions and subsequent organizational discontinuities, which were necessary in order to reap economies of scale.

FROM PRODUCT VARIATION TO ECONOMIES OF SCALE

Product variation was dominant for nearly fifty years. Two incentives for such product variation are clearly apparent. First, the application of automobile techniques to the needs of the clients, their adaptation to the physical constraints of snow traction and tread and ski technology called for variation. Second, general-purpose machinery and mechanics' know-how could be shared in the production of technologically proximate designs. By producing slightly different models for forest management and petroleum exploration, Bombardier could reduce the unit price for both models. He also used common components in different models: sprocket, tread and crazy wheels. Even after the introduction of the standard design of the Ski-Doo, some minor product variation continued. After the inventor's death, Bombardier Ltd. started in 1964 to engage in systematic market research. Different models with different price tags tried to appeal to different segments of the consumer market. Some models -- like the Elan -- sold for as little as $595, while the higher powered 'Cadillac' version -- the Elite -- sold for many thousands of dollars. Two brand names ('Ski-Doo' and 'Motoski') were used to keep the greater share of the market possible. The consumer could also choose between options and accessories. But as the market saturated after

1972, even this very limited scope of product variation narrowed: from seven different snowmobile series and twenty-two different models in 1970, only four series and ten different models were available to the customer in 1979. In this scope of choice, there were no systems design variations as there had been at the time of batch production. But as economies of scope tended to disappear, economies of scale became more important.

CRITICAL STRATEGIC DECISIONS AND ORGANIZATIONAL DISCONTINUITIES

The second aspect which is obscured by the apparent continuum in the increase of length of runs is the incidence of strategic redirection of the firm. There are at least three such critical points in Bombardier's history. The first was in the summer of 1936, when J. Armand decided to move to a plant and make manufacturing his main activity. The 1936/37 shift of operations involved a massive shift in the mode of operation.

The second critical historical juncture occurs twenty-two years later and took much longer to resolve. After the standard design for the Ski-Doo had been developed by J. Armand and his son Germain, the opportunity existed for mass production for the consumer market. But it is far from obvious that the inventor would have successfully steered the company firmly in that direction, had he survived the crisis. He disliked advertizing, institutionalized marketing systems and techniques and discriminatory pricing; also he liked to rely on skilled mechanics for constant technical improvements as opposed to unskilled assembly line workers. Until 1956, Bombardier Ltd. was rapidly losing its dominant share of the North American snowmobile market. Between 1958 and 1961, in spite of the menace of losing the dominant market position, J. Armand Bombardier was very involved in the development of the forestry device, the cutter-buncher. He invested in eight prototypes and much inventive effort in this design. Obviously, his priorities were technical rather than market determined. T.B. Fraser of the Quebec North Shore Paper Company claims that

> If J. Armand Bombardier had been spared, he might have done for the logging industry what he has done for the winter sports and transportation with the Ski Doo.

J. Armand Bombardier's death marked a decisive turning point. The family could no longer rely on the inventiveness of the master mechanic and the informal communication network he had with other mechanics. The family concern, under the leadership of his son-in-law, Laurent Beaudoin, a lawyer, decided to put all their investment in the Ski Doo. Between 1967 and 1973, the family company invested heavily in specialized machinery and assembly line equipment in order to reduce the unit costs. An organizational crisis had been resolved by a strategic decision.

No sooner had one been resolved than another crisis loomed. In 1972 the snowmobile market plummeted. Although its recovery was long expected, it failed to materialize. Bombardier Ltd. was then stuck with considerable excess capacity. In 1975, with the assistance of the Caisse des Dépôts du Québec, another strategic step was taken, this time towards diversification. In addition, with the acquisition of M.L. Worthington, Bombardier Ltd. decided to buy out other transport equipment firms, becoming a multi-product firm. The snowmobile slowly became a minor part in its overall sales, although the consumer and recreational market remained crucial. In the 1980s, the public transit market became the decisive one for the firm. Bombardier Ltd, however, relied now on multi-plant economies and an array of technical capabilities, and the future of the firm would never again be dependent on one product.

TECHNICAL SHIFT FROM PRODUCT TO PROCESS INNOVATIONS

Another condition was required before economies of scale could be fully reaped: technical developments had to shift from product to process innovation. Until 1952, all of Bombardier's innovations were product innovations. In the late 1940s some specialized machinery had been bought, but whatever process innovation there was remained at the level of individual or group know-how. But this did not imply formal engineering designs which could have an impact on equipment fabrication by Bombardier suppliers. In 1952, however, an unresolved problem provided an incentive to develop a machine. J. Armand Bombardier was dissatisfied with the slow and inadequate response that an American tire manufacturer was making to his demands for more economical production of continuous rubber treads for his snowmobiles. He invented and built a vulcanizing machine for his endless reinforced treads and tracks which allowed him to produce one every half-hour; as the tire manufacturer refused to develop the simple machine, he did it himself. Similar constraints also induced him to build a simple hydraulic press for the aluminum seat structure. The machines were simple enough to order, but he preferred to build them himself in his spare time rather than buy them at higher costs. In this way he acquired the intimate knowledge of the production techniques of his suppliers. As an inventor, he had a proclivity to do what was interesting rather than what may be considered to be immediately more economically efficient, so in 1961 he built three hydraulic presses, and a year later Canadian Vickers reproduced the set.

Tackling process technology may take various forms: learning to use general-purpose machine tools, adapting standard general-purpose machinery to a specific task with jigs and fixtures, conceiving and designing specialized equipment, inventing new machinery, manufacturing and commercializing. These forms of acquisition of process capability all constitute a continuum. Few firms master process technology in all of these forms. Bombardier mastered his production technology in most of them.

Although he took out a patent for his 1952 vulcanizing machine in order to insure his independence from rubber manufacturers, there was little that was novel in the process. As for the 1961 hydraulic presses to shape aluminum seat structures of the Ski Doo, he adapted well-known technology. As demand for Ski Doos soared, production runs put stress on the presses, and it became necessary to have the models rebuilt by a professional machinery maker, Canadian Vickers. His own three presses, after working alongside Vickers' for a few years in the Valcourt plant -- where the latter are still in operation -- were later retired to a museum. Not until a decade after the inventor's death in 1972, when market saturation put pressure on the firm to cut costs, did process innovations become frequent.

In 1972, new apparatus for making endless belts was patented. In the following year, patents were obtained for the assembly of the head lamp, the bobbie wheel and the muffler; in 1974, for the assembly of the ski bracket and for fitting the endless belts; in 1975, for the steering column construction; in 1976, for the windshield mounting and suspension spring adjustment. All these process innovations were aimed at reducing costs of mass production. Although during that same period there was renewed product innovation, these product innovations related to mass production process innovations.

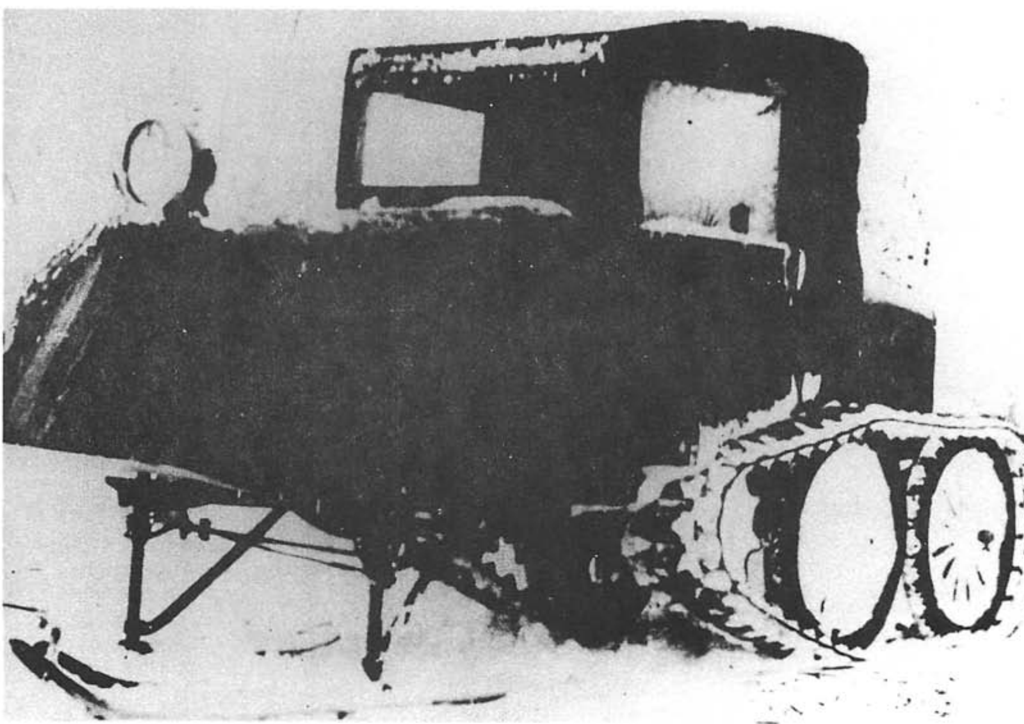
The product innovations of the 1970s were minor systems adjustments, such as chain tensioning systems, sheave drives, blades for suspension, ski legs, suspension wheels, tension release mechanisms, adjustments for the suspension, ski snow deflectors, disc brakes, air intake silencers and voltage regulators. All these product innovations made the snowmobiles more reliable but did not change the basis system. The power of the innovation came from the combination of all these innovations and the basic coherence between all of them. The development of support and ancillary components also induced external innovations in component manufacturing.

FROM SYSTEM TO INDUSTRIAL COMPLEX

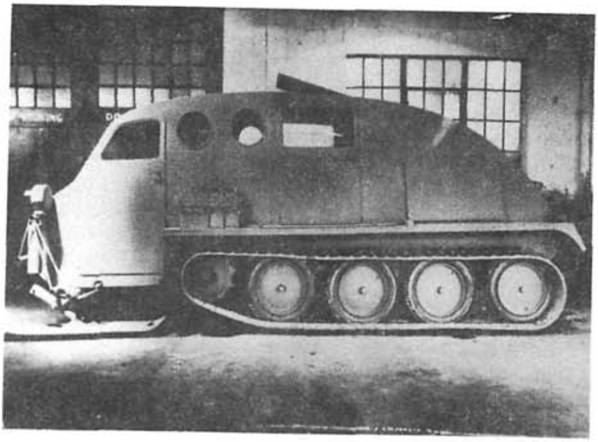
One of the preconditions of mass production and development of related process innovations was the emergence of a simple, reliable design. This occurred in two phases: first in 1935 for the *auto-neige* with the motive sprocket wheel and double reinforced tread; and later in 1958/59 with the single tread. The opportunity for mass production was only exploited after the second phase. As the Ski Doo became commercially dominant, it set the pattern in the industry and became accepted as the dominant engineering design. The core of this technical system -- the motive sprocket wheel and reinforced tread -- had varied little since 1935. Materials changed, designs had been slightly altered and special applications developed, but the core conception remains the same. Around a standardized core technology, ancillary and support technology developed to make it more efficient. A 'technical system' evolved.

The ancillary and support technologies developed were numerous and included transmissions, gears, drives, motors, brakes and suspensions. These ancillary technologies considerably improved the efficiency of the snowmobile technology. In some

EARLY VERSIONS: Left--the *motoneige* of the Valcourt Hotel in 1927; below--a 1935 model. All photos courtesy of the Musée J. Armand Bombardier, Valcourt, Québec.



LATER MODELS: Top to bottom--a 'B-1'; one version of 'Muskeg'; the 'Ski-Doo' of 1959.



cases, the improvement made all the difference between reliability and frequent breakdowns, adoption or rejection. The search for improvements seems to have had its own autonomous momentum with one problem leading to another. Bombardier's patent records reflect this shifting technical agenda and focus of improvements. After the initial 1958/59 design, a pulley transmission was developed to increase the speed (1962 patent). Then bearing seals were developed (1965 patent). Snow accumulated on the tread, slowing the vehicle down periodically and a snow expelling system was devised (1965). As the vehicle increased its acceleration capacity, the transmission system represented a limit to its performance, so an automatic transmission was developed (1965). As the vehicle needed to change speeds more frequently than a road vehicle, a variable speed transmission system was developed (1968). The speedy vehicle then required a new braking system and a patent was taken out in 1970. The rapid vehicle then provided a rocky ride and a suspension system was patented in 1972. Each technical achievement made Bombardier focus on the next limit to the performance of his vehicle, lending its own logic to the technical development. Thus evolved an interdependent system.

The development of a system also had its business dimension. J. Armand Bombardier paid close attention to the control of manufacturing for each component, whether sprocket, tread, plastic parts or aluminum parts. Almost all component technologies were developed by him, except for Arctic Cat's front ski suspension. This technical control implied direct business control of subsidiaries, usually through a relative in the Eastern Townships. The rubber components in Roskin Falls, for example, were controlled by his son Germain.

The new management was to continue this strategy of upstream control of components, sometimes by acquiring financial control of firms, as in the case of Lohnerwerke G.M.B.H. of Vienna. The new management would also extend this vertical integration downstream to marketing, accessories, public education, regulation, sport promotion, resort and trail expansion. Much of the economic benefits of the snowmobile production accrued to the Québec Eastern Townships only because 80% of all components of the product are directly controlled by the firm and are located in the region.

The technological system of the snowmobile is accompanied today by a modest but significant complex of interrelated industrial activities, linking the main factory with component suppliers. The industrial techniques for which the firm has competence comprise bearings, springs, wheels, voltage regulators and lubrication devices. The automotive techniques include steering, transmissions, suspensions, brakes, drives, clutches and mufflers. Various shoes are used for the vehicles: skis, tracks, wheels. The firm uses different materials: aluminum, plastics, fibreglass and rubber. Furthermore, it has acquired competence in corresponding production techniques. The firm has experience in the following markets: military, transport, recreational municipal, mass consumer and many industries such as foresty and petroleum.

In retrospect, there are many reasons other than technical to Bombardier's market leadership in the North American snowmobile market. Although we will not examine them here, let us just mention the most probable ones: after the inventor's death, downstream integration, horizontal concentration in the industry, a 'shake out' in the industry, investment financing and government regulation of the industry. All these must have contributed to Bombardier still controlling 30% of the North American market in 1980. Without the market domination, the economic benefits of the technological development would have been more modest.

BENEFITS

The industrial benefits of the snowmobile are obvious today. In the 1970s, direct employment in the Valcourt plant alone ranged from 1,500 to 3,000. Many neighbouring villages around Valcourt also have benefited from the establishment of component manufacturers: Rockland Industries' rubber manufacturing in Kingsbury, Roski in Roskin Falls, Lasalle Plastics, Drummond Automatic Plating, Ville Marie Upholstering, all in the Eastern Townships of Québec. The manufacturing of snowmobiles in Valcourt generated 'upstream demand' for components and employment. Conversely, this employment has since generated income and demand for other goods -- 'downstream effects.' Because the snowmobile is a consumer good, its manufacturing has generated 'final demand linkages,' which means snowmobiles being purchased from the incomes resulting directly and indirectly from their production in and around Valcourt.

This economic multiplier effect has been accompanied by a technical multiplier effect. The know-how required in one area has spun off into other industries. Some of the subsidiaries are now technological innovators in their own right. Also, the material culture of Canadians and northern people has been transformed by an indigenous innovation. In 1978, parts, accessories and fuel sales resulting from the sales of snowmobiles -- first order indirect sales -- amounted to $400 million in Canada. Such an economic impact, however, does not accrue from all innovation but only from a systems innovation in the consumer goods sector, given mass production and 90% of components controlled by the firm. The process of translation of technological advantages into economic benefits is not direct, and not all innovations can expect such an impact.

SOME IMPLICATIONS

The significance of the Bombardier story for Canadian development cannot yet be clearly evaluated. Is the early Bombardier story the most representative and the late mass production an exception? If innovation in Canada were confined to customs adaptation of existing systems design, the economic returns which we could expect would be limited to that of an early adopter of foreign technology. On the other hand, if Canada had developed complete systems technologies which are fairly central to its production and way of life, the economic effects of the innovation may be expected to be much greater.

Mass-produced innovations such as the Ski Doo have a much greater effect than those which are produced in batch and shorter runs. Our own survey[10] has identified only a limited number of innovations produced in series or related to mass production since 1945: factory-produced mobile homes, Orenda gas turbine engines, PT6 gas turbine jet engines, the Chip 'N Saw, mobile spars for grapple yarding, Koehring whole-tree short wood harvesting equipment, the papriformer, the oxygen steel process, CO2 immobilization of animals for slaughter, particle boards, electromagnetic airborne surveying systems, sclair polyethylene pipes, semi-continuous casting of electrolytic copper slabs, flight simulators, inertial navigation systems, intermediate diazepan (valium), 2-40 herbicides, teller computer for credit unions, computer booking, unitron hearing aids, electronic recognition of cheques, unit train systems, pump to cash register electronics, piggyback trailers for rail, auto-toll telephone systems, high-tension electric power transmission, remote farm radio telephones and the Candu reactor. It has not yet been possible to evaluate how marginal, or central, these mass production innovations are.

CUSTOM BIAS

In the equipment sector where we conducted a phone survey, some forty manufacturers represented a few hundred innovations covering machine shops, mechanical, electrical and electronic equipment, instruments, aircraft and avionics. We found that a majority of innovations was produced only in a custom and small batch mode. Although small firms were more prevalent in the custom and batch production, large firms were equally involved in custom and line production. As the equipment sector is significant for technological development, this custom bias has its importance. The extent to which equipment manufacturers standardize their products will affect their capability to diffuse the products and act as pressure groups for technological change. However, the machinery sector is relatively marginal in Canadian industry.

If we turn to industries which are more central to Canada, a custom orientation is clear for plastic fabrication, industrial chemicals, shipbuilding and small agricultural implements. But mass production techniques are the rule in sawmilling, newsprint, non-ferrous metals, iron and steel, cable and wire. The historical record has privileged the cases of mass-produced innovations such as stoves, sewing machines, cooking ranges and the fordson (105).[11] But mass operations in logging may have been accompanied by specialty designs, somewhat unreliable, alongside the dominant German Stihl chainsaw.[12] Although the Canadian sawmills were as massive, if not more so, than their US counterparts, the great variety of Canadian sawmilling equipment does not indicate the presence of any corresponding standardized equipment supplier.[13] In construction, on the other hand, many materials and homes in Canada seem to have been mass produced early on.[14] More exploration of the historical record would be required, however, to determine to what extent the large proportion of customized innovation limited the dynamic effects of innovation. In such an examination, the relative proportion of custom, batch or line production innovations is less important than the coupling of a capital goods supplier with the user industry.

WHAT A CUSTOM BIAS IN INNOVATION WOULD EXPLAIN

A custom bias of innovation appears to be a logical explanation for many features of Canadian development. The relatively high level of innovation in Canada could be partly explained by its extreme specialization, given the low proportion of innovators who perform Research and Development or take out patents. In unit production, product development is indistinguishable from production itself, and the machine shop setting in Canada may constitute both the research and development and production facility.[15] It may also explain why very small firms in Canada are more R & D intensive per sales than in the United States, and the fact that design, tooling up, pre-production and testing do not represent such important expenditures as they do in the USA.[16] If production runs are short, no such expenditures would be required. This engineering, design and production tooling deficiency, however, need not stop -- as we have seen in the early Bombardier experience -- a firm from modifying its products in response to the needs of specific clients and thus reaping economies of scope. Such custom innovation would not induce process innovation or much fixed investment. In other words, this particular type of innovation would not be growth-inducing in Schumpeter's and Kuznets' sense. The paradox of an innovative country without internal dynamic centres of growth might be partly resolved if the custom bias of Canadian innovation were confirmed.

SPECULATING ON POSSIBLE CAUSES

Such an hypothesis may also have likely causes. In examining the possible factors of such a custom bias, one can look at a number of negative constraints which hinder the passage of innovation from custom to mass production: lack of growth capital in a banking system which privileges large commercial operations and short-term loans with high interest rates that disfavour medium- and long-term industrial investment. The quantum leap involved in making a transition to production in series involves financing stock, inventories and capital outlays. Innovators find little or no financial support even when they have orders in hand. Oligopsony -- the control of demand by a few -- may hinder 'supplier initiative' in the capital goods sector. The tight oligopolistic concentration of Canadian industry may relegate innovation to the margin of each oligopoly, each using expansive innovations against the other such as aluminum against copper, plastic against metals, corn against sugar. Reliance on easily-accessible foreign technology may encourage merely adaptive innovations to fit the specific Canadian context, use its available materials and energy, draw on its specific work skills and traditions and mesh with its regulatory and political environment. Also, subsidiaries within multinational operations, be they Canadian or foreign, may not have the prerogative to develop complete systems. Defence production sharing with the United States seems to favour the use of Canada as a flexible machine shop for prototype development, while large-run production will usually occur in the United States.[17] In our survey, we have encountered some equipment manufacturers and defence contractors who bragged about being the 'Rolls Royce of the industry (with) 15 to 20% higher prices.' Such a special type of technical leadership may not generate substantial foreign trade earnings, induce growth or contribute to a dynamic economy.

An exploration of this hypothesis would also have to include a look into countervailing forces such as the opening of free trade, the Auto-Pact and the Defence Production Sharing Agreement, along with areas of concentrated homogenous markets such as banking, medicare and the wage structure. We do not pretend that the custom bias of innovation in Canada is an established fact but only that the hypothesis is worthwhile exploring in order to resolve the paradox of an innovative country wtihout the usual attributes of a technologically-dynamic economy.

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NOTES

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8. The sources of this article are mainly from secondary accounts, including: J.R. André Bombardier, 'J. Armand Bombardier and All Terrain Vehicles,' (Ontario Science Centre, 1979); J.A. Bombardier Museum pamphlets 'J. Armand Bombardier--Inventor,' '... Puis vint le Ski-Doo'; official written sources of Bombardier Ltée., such as the collection of annual reports, product brochures, Annual Vacation Guide, Snowmobile Safety Handbook, parts catalogues. Other printed sources include: Jean Robidoux et Louis Maréchal, 'Facteurs de croissance de l'industrie Canadienne de la motoneige, 1958-1978,' Department of Industry, Trade and Commerce (Ottawa, 1978); Gideon Rosenbluth, 'Competition Policy Bombs Again: the Bombardier Case,' Canadian Economic Association (Halifax, 1981); special issue of *Le Soleil*, 8 September 1973: '1,000,000: Ski Doo, le p'tit géant de Bombardier: un million de motoneiges.' In addition to printed sources, three visits were made to the Valcourt plant and four visits made to the Museum and Bombardier Foundation in 1981. A few managers of the company were questioned on specific issues, in particular, Peter Ohrt. Alphonse Bombardier, the inventor's first accountant and then curator of the museum, gave us two interviews and checked the accuracy of our account.

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